PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in or relating to Sealing Devices

We, ROLLS-ROYCE LIMITED, a British company of Nightingale Road, Derby, Derbyshire, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

This invention relates to sealing devices for sealing between two relatively rotatable members.

Seals which seal between two relatively rotatable members and which are rigidly fixed to one of the members suffer from several disadvantages; in order to accommodate manufacturing tolerances, thermal distortion and possibly mis-alignment, it is necessary with such seals to work at a larger clearance than is otherwise desirable.

This invention provides a means for sealing between two relatively rotatable members in which the seal is not rigidly fixed to one of the members and which helps to overcome these disadvantages.

According to the present invention a sealing device for sealing between two relatively rotatable members comprises a seal part which in normal operation of the device separates a high gas pressure zone and a low gas pressure zone, the seal part being sealingly mounted on one of said members so as to permit axial movement of the part with respect to the one member, said seal part having two sealing projections towards the second member each of said projections having a face coacts with the second member in normal operation of the device to reduce the flow of gas past the seal part in which said seal part is substantially U-shaped in cross section, the concavity of said U-shape enveloping the circumference of a radially projecting part of said second member, said projections projecting from the limbs of said U-shape towards one another and coacting with opposite faces of said projecting part or with one face of said part and one face of a second radially projecting part, and in which the intermediate gas pressure existing between the two projections is applied to at least one face of the seal part to maintain the seal part, in normal operation, in an equilibrium axial position where each of the faces of the projections is maintained at a steady gap from the corresponding face of the radially projecting part or parts of said member.

Preferably the seal part comprises an annular part, coaxial with the axis of relative rotation of the members.

Said part may be sealed to said one member at a position radially inward of the outer extent of the part, so that said low pressure acts on more than one face of said part.

Said part may be made up of a main part and a sub part, said main part being annular and sealed to said one member and said sub part being annular and carrying one of said projections, said sub part being sealed to said main part so as to be axially moveable with respect to said main part.

The invention will now be described, merely by way of example, with reference to the accompanying drawings in which the seal device of the invention is shown applied to a gas turbine engine and in which: —

Figure 1 shows a partly broken away elevation of a gas turbine engine incorporating a sealing device according to the invention;

Figures 2 and 3 show, diagrammatically, sections of devices according to the invention applied to the turbine of a gas turbine engine;

Figure 4 shows a diagrammatic section of a further device according to the invention applied to the turbine of a gas turbine engine; and

Figure 5 is a section on the line 6—6 of Figure 5.

In Figure 1 is shown a simple gas turbine engine 10 having an axial flow compressor 11, a combustion section 12, a turbine 13 and a nozzle 14 in flow series.

It is preferable if a seal can be interposed between the shroud 18 at the periphery of the turbine 13 and the casing 19 of the engine, and a seal 20 according to the invention is shown diagrammatically in Figure 1.

The seal 20 is shown in detail in Figures 2 and 3 with a modification of the seal 20 being shown in Figure 4.

A seal 20 according to the invention is shown in figure 2. The seal 20 is required to seal between the shroud 18, at the periphery of the blades 50 of the turbine 13, and the casing 19 of the engine.

To this end there is mounted from the shroud 18 an annular fin 51 which projects radially from the outside of the shroud 18. The fin 51 has flat annular faces 52 and 53 which are normal to the axis of the engine 10 and which face upstream and downstream of the engine 10 respectively. The faces 52 and 53 co-operate with parallel faces of projections 54 and 55 respectively of an annular seal part 56 which is substantially U-shaped in cross section and which envelopes between its limbs the fin 51.

A radially inward annular projection 57 from the casing 19 has an axially projecting annular flange 58 in which is formed an outwardly facing groove 59. A sealing ring 60 is carried in the groove 59 and co-operates with a cylindrical surface 61 of the part 56 to seal the part 56 to the flange 58. The part 56 is sealed to the flange 58 at a position radially inward of the outer periphery of the part 56 so that the pressure existing downstream of the part 56 acts on more than one face of the part 56.

In the embodiment shown, the part 56 is made up of two annular pieces 62 and 63 which are held together by bolts 64. This is to enable the part 56 to be assembled around the fin 51.

The piece 62 carries splines 65 which engage with splines 66 on the casing 19 to prevent rotational movement of the part 56 with respect to the casing 19.

The part 56 will be seen to be axially moveable with respect to the casing 19, and will move to take up an equilibrium position under the influence of gas loads.

Let the pressure upstream of the gap between the faces of 52 and 54 (i.e. the pressure in the space to the left of the seal 20 as shown in the drawing) be P5; let the pressure downstream of the gap between the faces of 53 and 55 be P6 (i.e. the pressure in the space to the right of the seal 20 as shown in the drawing). Let the pressure in the space between the gaps between the faces of 52 and 54 and 53 and 55 be P7.

Let the area between the projection 55 and the surface 61 taken in a plane perpendicular to the axis of the engine 10 be A6 and let the area between the surface 61 and the projection 52 taken in a plane perpendicular to the axis be A5.

For equilibrium of the seal part 56:

$$(P_5 - P_7)\ A_5 = (P_7 - P_6)\ A6$$

By adjusting the areas A5 and A6 the equilibrium position may be adjusted. Once the seal part is in equilibrium, it will be seen that movement of the part 56 towards the right hand, low pressure zone, will cause the pressure in the intermediate space between the faces 52 and 54 and 53 and 55 to fall, thus causing the part 56 to tend to gain its former position.

Similarly displacement of the part 56 to the left causes the pressure in the intermediate space to increase, tending to move the part 56 back to its equilibrium position.

In Fig. 3 is shown a further embodiment of the invention. Basically the device of Fig. 3 is similar to that of Fig. 2, and many of the reference numerals used in Fig. 2 are again used to denote similar parts in Fig. 3.

It will be appreciated that should the faces of projections 54 or 55 of the seal 20 of Fig. 2 wear away for any reason, the seal 20 becomes less efficient. In order to overcome this in the embodiment of Fig. 3 the projection 54 is carried on a sub part 70.

The sub part 70 is annular and is sealed to the part 56 by a piston ring seal 71 so that the seal part 70 is capable of a limited axial movement with respect to the part 56. The projection 54 of the sub part 70 co-acts with the face 52 of the fin 51 in the same manner as in the embodiment of Fig. 2. The sub part 70 has on its inner face a labyrinth seal 72 which co-acts with the axially extending circumferential face 73 of the shroud 18. Thus it will be seen that the clearance between the labyrinth seal 72 and the face 73 will not be affected by relative axial movement of the sub part 70 and the turbine blades 50.

Splines 74 on the sub part 70 engage with splines 75 on the part 56 to preclude any relative rotational movement between the sub part 70 and part 56. Otherwise, the construction of the seal of Fig. 3 is similar to that of Fig. 2.

If the dimensions of the seal are chosen correctly, then the influence of gas loads will be such as to cause sub part 70 to move towards the fin 51 and take up the effect of any wear which might develop on the co-acting surfaces of the seal part 56 and the fin 51. Let the pressures in corresponding parts of the device of the Fig. 3 be denominated in the same way as those of Fig. 2. There will, however, be an additional pressure which extends between the labyrinth seal 72 and the face 52, let this pressure

be called P8. In the same way let the projections of the various areas which are the same as those in Fig. 2 be denoted in the same way but let the area between the projection 54 and the seal 71 be A8 and let the area between the seal 71 and the seal 72 be A9. For equilibrium of the seal, two conditions obtain, that:

$$(P_7-P_6)\ A_8=(P_5-P_7)\ (A_5-A_8)$$

and

$$(P_5-P_8)\ A_9=(P_8-P_7)\ A_8$$

The self-positioning action of the seal part 56 is exactly similar to that of the embodiment of Fig. 2. However, should any of the faces of 54, 55 or 52, 53 of the embodiment of Fig. 4 wear away due to friction, then the pressure P8 will be reduced (the gap interconnecting P7 and P8 will be made larger) and the sub part 70 will tend to move towards the fin 51 to take up the wear.

Thus the embodiment of Fig. 3 will be seen to be less sensitive to wear than that of Fig. 2.

A further embodiment of seal, having similar characteristics to that of Fig. 2 and being independent of wear, is shown in Fig. 4. As in Figs. 2 and 3 the seal is interposed between the shroud 18 at the periphery of the turbine blades 50 and the casing 19 of the engine 10.

In this case two annular fins 80 and 81 are formed on the shroud 18, the fins projecting radially of the turbine and being axially displaced one from the other. An annular seal part 82 lies radially outside of the fins 80 and 81 and has two inward projections 83 and 84 which have faces 85 and 86 which coact with the downstream axially-facing sides of the fins 80 and 81 respectively to form a seal.

An annular, axial projection 87 from the upstream projection 83 is sealed to a 'piston ring' seal 88 which seals the projection 87 and hence the part 82 to a radial projection 89 from the casing 19 and hence seals to the casing 19. Thus the part 82 has a limited amount of axial movement while still remaining sealed to the casing 19.

A number of small bleed holes 90 extend through the projection 84 and connect the space 91 between the projections 83 and 84 with the downstream side of the seal.

It will be seen that this seal functions in the same fashion as that shown in Fig. 2. Again, if the seal part moves from an equilibrium position which may be set up by suitable choice of dimensions of the seal, the ratio of the areas available for entry of high and low pressure gas to the space 91 will change, altering the pressure in the space 91 so as to tend to move the part 82 back to its equilibrium position.

Using the notation shown in the drawing, for equilibrium of the seal part 82.

$$A_{10}\ (P_7-P_6)=A_{11}\ (P_5-P_7)$$

This seal has the advantage that wear of the faces 85 and 86 does not affect the equilibrium gap between the faces 85 and 86 and the fins 80 and 81; such wear will merely result in the part 82 moving to the left of the drawing to take up the wear.

In order to assemble the part 82 over the fins 80 and 81, the part 82 is formed with an axial split 92 (see Fig. 5) in it which enables the part 82 to be expanded and passed over the fins 80 and 81. When this has been performed, a continuous ring 93 is forced over the outside of the part 82 until it seats in a groove 94 which locates the ring 93 axially on the part 82. The ring then prevents the part 82 from expanding and escaping from the fins 80 and 81.

The depth of the groove 94 and the extent by which the inside diameter of the ring 93 is less than the outside diameter of the part 82 are both exaggerated in the drawing; in practice the ring would only seat a few thousandths of an inch in the periphery of the part 82.

This method of assembling and retaining the part 82 may be used for the similar parts 56 shown in Figs. 3 and 4 instead of the bolted-together construction shown in these figures.

It will be noted that there are no splines shown in the embodiment of Fig. 5 to prevent rotation of the part 82 with respect to the casing 19. These splines are optional features in all the embodiments and their use or otherwise depends on the particular application of the device.

Although in the embodiment described the seal part has been sealed to the static member by a piston ring seal, it is possible to attach the seal part by a bellows. In this case it would be possible to delete the splines which are described above.

WHAT WE CLAIM IS:—

1. A sealing device for sealing between two relatively rotatable members comprising a seal part which in normal operation of the device separates a high gas pressure zone and a low gas pressure zone the seal part being sealingly mounted on one of said members so as to permit axial movement of the part with respect to the one member, said seal part having two sealing projections toward the second member each of said projections having a face which co-acts with the second member in normal operation of the device to reduce the flow of gas past the seal part in which said seal part is substantially U-shaped in cross section, the concavity of said U-shape enveloping the circumference of a radially projecting part of said second member, said projections projecting from the limbs of said U-shape and coacting with opposite faces of said projecting part or with one face of said part and one face of a second radi-

ally projecting part and in which the intermediate gas pressure existing between the two projections is applied to at least one face of the seal part to maintain the seal part, in normal operation, in an equilibrium axial position where each of the faces of the projections is maintained at a steady gap from the corresponding face of the radially projecting part or parts of said second member.

2. A sealing device as claimed in claim 1 in which the seal part comprises an annular part, coaxial with the axis of relative rotation of the members.

3. A sealing device as claimed in claim 2 in which said part is sealed to said one member at a position radially inward of the outer extent of the part, so that said low pressure acts on more than one face of said part.

4. A sealing device as claimed in claim 3 in which said part is made up of a main part and a sub-part, said main part being annular and sealed to said one member and said sub-part being annular and carrying one of said projections, said sub-part being sealed to said main part so as to be axially moveable with respect to said main part.

5. A sealing device as claimed in any of claims 1 to 4 and in which said projections are at different radii.

6. A sealing device as claimed in any of claims 1—5 and in which said part is able to be separated into two annular pieces to enable said part to be easily assembled enveloping said annular projection.

7. A sealing device as claimed in claim 4 and in which said sub-part carries an additional labyrinth seal coacting with an annular axially extending face of said second member so that its clearance is unaffected by relative axial movement of said sub-part and said second member.

8. A sealing device as claimed in any previous claim and in which said part is sealed to said one member by a piston ring seal.

9. A sealing device as claimed in claim 4 and in which said sub-part is sealed to said main part by a piston ring seal.

10. A sealing device as claimed in any previous claim and in which said part carries axial splines which engage with axial splines on said one member so as to prevent relative rotation of said part and said one member.

11. A sealing device substantially as shown and described with reference to Fig. 2 of the accompanying drawings.

12. A sealing device substantially as shown and described with reference to Fig. 3 of the accompanying drawings.

13. A sealing device substantially as shown and described with reference to Fig. 4 of the accompanying drawings.

14. A gas turbine engine provided with a sealing device as claimed in any of the foregoing claims.

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2 SHEETS

SHEET 1

FIG.1.

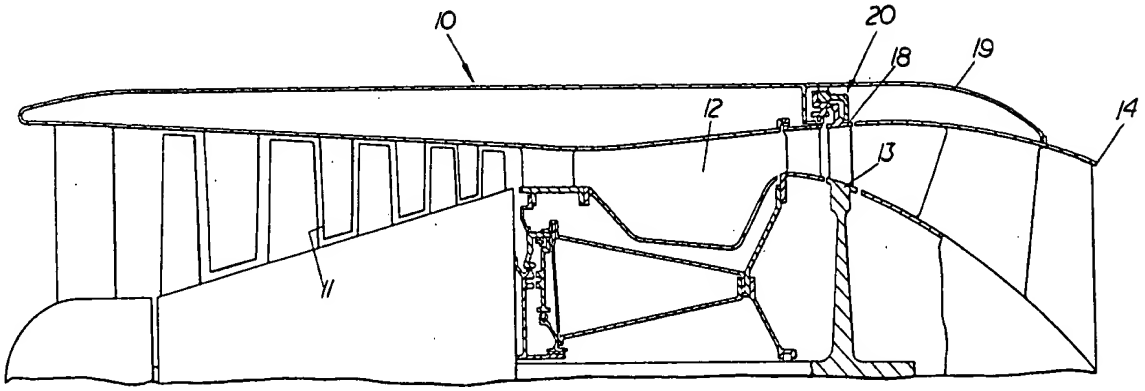


FIG.4.

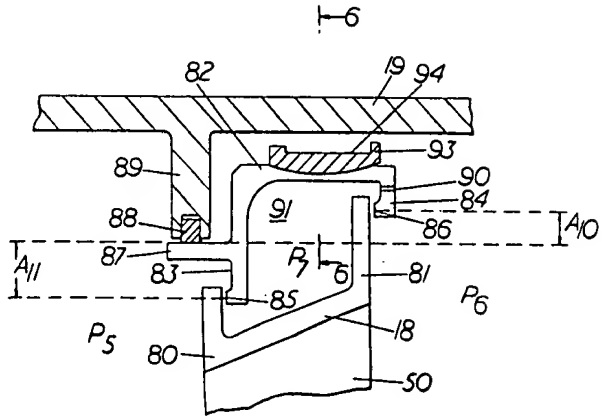
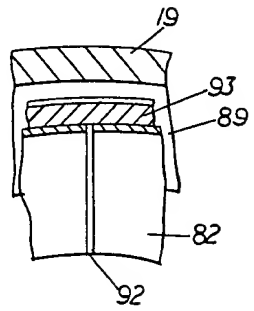


FIG.5.



996,546 COMPLETE SPECIFICATION
2 SHEETS This drawing is a reproduction of the Original on a reduced scale.
SHEET 2

FIG. 2.

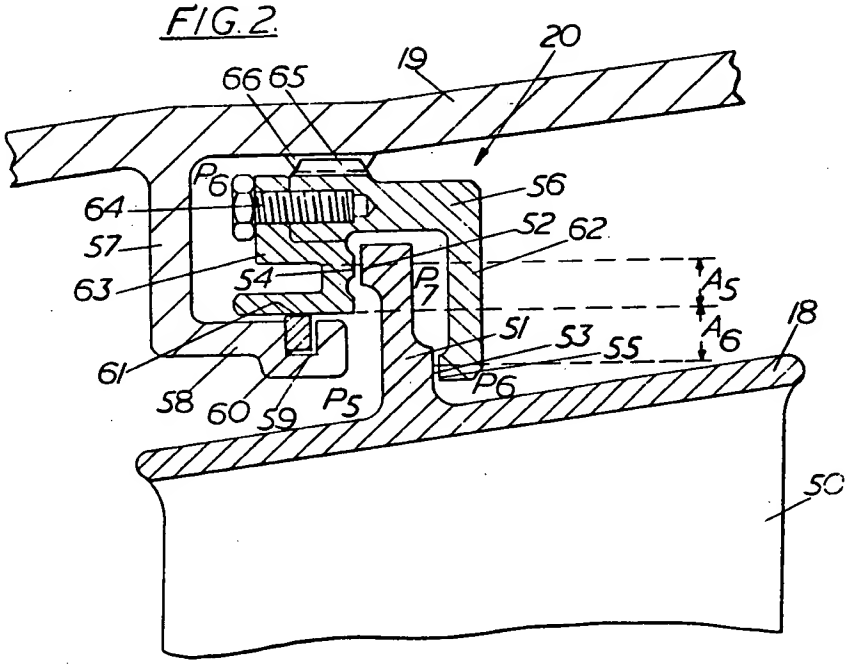


FIG. 3